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CESMII
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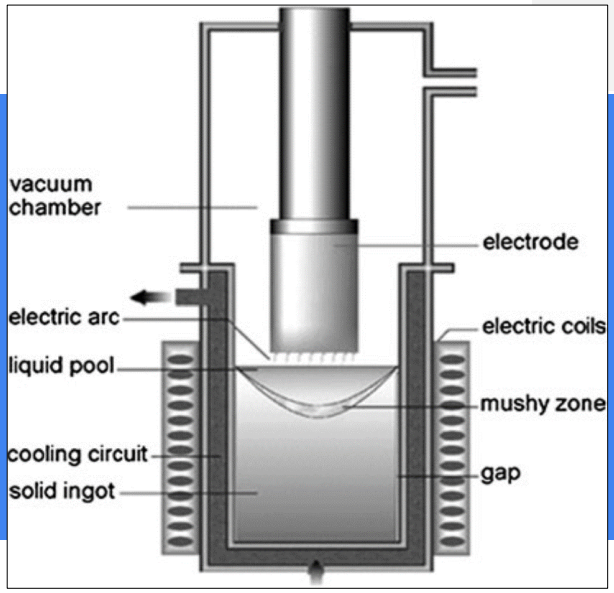
PROJECT CASE STUDY

Improved Vacuum Arc Remelting Processing



PROJECT LEAD

Raytheon

PROJECT TEAM

Purdue, Connecticut Center for Advanced Manufacturing (CCAT)

PROJECT OBJECTIVE

Develop a simulation/testing framework to determine the feasibility of using ultrasound to mitigate Dirty White Spots (DWS) in the Vacuum Arc Remelting (VAR) process. If it can be shown that this method effectively reduces the frequency of DWSs, turbine parts can be double melted as opposed to requiring triple melting.

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Process Modeling Validates Methods for Reducing Turbine Parts Manufacturing Energy Consumption by 30%

BENEFITS TO OUR NATION

Reducing turbine part manufacturing energy consumption will significantly reduce the industry's carbon footprint and contribute to American industry's environmental sustainability. Moreover, the decreased energy demand will reduce the strain on the North American power grid, enhancing grid reliability and resilience.

In 2022, the US Gas Turbine market exceeded $11 Billion. Reducing manufacturing costs will lead to increased competitiveness and profitability, creating more manufacturing jobs and driving American economic growth.

BENEFITS TO INDUSTRY

Eliminating the requirement for a third melting step for turbine parts will result in >30% energy savings over the current practice. For just the turbofan engine industry, a 30% reduction in energy usage during the remelt process translates to an energy savings of 264 GWh. If the marine, turboprop and power engine industries eliminate the 3rd remelting phase, their annual energy consumption will be reduced by 600GWh.

PROJECT DESCRIPTION

TECHNICAL APPROACH

In the proposed program, a novel coupled experimental / modeling approach will be pursued to investigate the feasibility of using ultrasonic waves to mitigate crown formation and if formed, break them off early to ensure complete remelt of the particles falling into the melt pool. The proposed program entails 1) Multiscale solidification models to quantify the effect of ultrasound on crown formation; 2) Crown vibration and melting models for ultrasonic feature optimization to mitigate risk of fall-in particles to DWS formation; 3) Specimen design, manufacturing, and experimental testing for model development, calibration, and validation.

ACCOMPLISHMENTS

- Developed a workable 3D transient VAR process model, including heat, mass, momentum, species transport and electromagnetics and solid-liquid phase change.
- Developed a workable transient solidification/melting model, including dendrites growth, composition segregation and effect of latent heat. The model includes effects of wave attenuation in the regime when “cold boiling” or acoustic cavitation is not observed.
- Modal analysis has been performed and demonstrated that low frequency ultrasound does not cause crown resonance and corresponding failure.

DELIVERABLES

- Delivered multiscale VAR model to predict the effect of ultrasound on solidification.
- Delivered physics-based multiscale model, validated with experimental testing data.
- Delivered fall-in particle model and experimental data from ultrasonic fracture testing.

REUSABLE OUTCOMES / SM MARKETPLACE

Integrated Computational Materials Engineering based predictive models to prevent dirty white spots through ultrasonic excitation are broadly applicable to the Vacuum Arc Remelting industry, for aerospace, marine, and other power generation applications.

RESULTS

↓ 30%

Smart Manufacturing yields a 30% reduction in energy consumption for turbine part remelting.

↓ 264GWh

US turbofan parts manufacturers will save 264GWh annually by

↓ 600GWh

US marine, turboprop and power turbine parts manufacturers will save

PROJECT DETAIL
Budget Period: BP2 – BP5
Submission Date: 3/17/2023
Sub-Award (contract) Number: 4550 G YA090
SOPO: 2311

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